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PROJECT KIWI ONE CRUISE REPORT

William H. Thorp, et al

Naval Underwater Systems Center  
Newport, Rhode Island

12 February 1973

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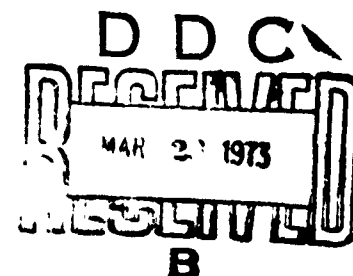
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**Project KIWI ONE Cruise Report**

**WILLIAM H. THORP**  
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12 February 1973

**NAVAL UNDERWATER SYSTEMS CENTER**

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## ADMINISTRATIVE INFORMATION

The work outlined in this document was supported by the following NUSC Projects and NAVSHIPS PMS-302-4 Exploratory Development Project:

<u>Project No./Title/ Principal Investigator</u>	<u>Navy Subproject and Task No./ Project Manager</u>
A-626-02 Biological Reverberation as It Affects ASW Operations (U) C. L. Brown, Code TA13	SF-52-552-020, -004, -080 A. Franceschetti, NAVSHIPS PMS-302-441
A-650-01 Underwater Sound Propagation Experi- ments for Sonar Prediction and Design (U) W. H. Thorp, Code TA112	SF-52-552-020 J. Reeves, NAVSHIPS PMS-302-44
A-650-04 Reverberation Characteristics for Active Sonar Design and Performance Pre- diction (U) N. P. Fisch and R. K. Dullea, Code TA111	SF-52-552-080, -081 J. Reeves, NAVSHIPS PMS-302-44
A-650-05 Ambient Noise Characteristics Affecting Sonar and Physical Oceanography (U) R. W. Hasse, Code TA A. J. Perrone, Code TA112	SF-52-552-020 J. Reeves, NAVSHIPS PMS-302-44

ACCESSION BY	
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DISTRIBUTION AVAILABILITY CODES	
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REVIEWED AND APPROVED: 12 February 1973

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New London, Connecticut 06320

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified

1. ORIGINATING ACTIVITY (Corporate author)  
Naval Underwater Systems Center  
Newport, Rhode Island 02840

2a. REPORT SECURITY CLASSIFICATION  
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

PROJECT KIWI ONE CRUISE REPORT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Summary Report

5. AUTHOR(S) (First name, middle initial, last name)

William H. Thorp  
William R. Schumacher

6. REPORT DATE

12 February 1973

7a. TOTAL NO. OF PAGES

34

7b. NO. OF REFS

3

8a. CONTRACT OR GRANT NO.

9. PROJECT NO.

A-626-02, SF 52 552-020, -004, -080

A-650-01, SF 52-552-020

A-650-04, SF 52 552-080, -081

A-650-05, SF 52 552-020

9a. ORIGINATOR'S REPORT NUMBER(S)

TD 4455

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Department of the Navy

13. ABSTRACT

This document contains a chronology of the biological and underwater acoustic tests during Project KIWI ONE, between 4 April and 12 June 1972, in areas of the North Atlantic and South Pacific Oceans, the Gulf of Mexico, and the Caribbean Sea. Objectives, problems, and accomplishments relative to the four separate phases and the planned events of each are described.

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Acoustic Volume Scattering						
Ambient Noise versus Depth						
AUTOBUOY						
Deep-Scattering Layer						
DSENZ (Defence Scientific Establishment of New Zealand)						
JOAST (Joint Oceanographic Acoustic and System Tests)						
Project KIWI ONE						
Propagation-Loss Prediction						
TABS (Telemetering Acoustic Buoy System)						
Low-Frequency Propagation-Loss and Ambient-Noise Measurements						
MABS (Moored Acoustic Buoy System)						
Ocean Acre						

### ABSTRACT

This document contains a chronology of the biological and underwater acoustic tests during Project KIWI ONE, between 4 April and 12 June 1972, in areas of the North Atlantic and South Pacific Oceans, the Gulf of Mexico, and the Caribbean Sea. Objectives, problems, and accomplishments relative to the four separate phases and the planned events of each are described.

## ACKNOWLEDGMENTS

To an unusual degree the operational success of Project KIWI ONE must be credited to the efforts and contributions of a large number of organizations and individuals. Any omission in the following recognition is the result of oversight, and for this the authors apologize.

In acknowledging the major support of the U. S. Air Force, we wish to cite in particular the outstanding cooperation of the 9th Weather Reconnaissance Wing at McClellan AFB, which supplied the drop aircraft; the 2nd and the 15th Air Forces at Barksdale AFB and March AFB, which supplied the aerial tankers; the Odgen and Oklahoma Air Material Areas, which conducted the Air Force certification of the Mk-94 SUS charges; the 24th Special Operations Wing at Howard AFB, which provided staging and communications facilities; and the 61st Military Assistance Wing at Christchurch, New Zealand, which hosted the drop aircraft and tankers at the New Zealand end of the flight.

In similar measure, the able support of COMFAIRWING 11 is gratefully acknowledged. The extensive aid and personal attention given to Project KIWI ONE by Mr. A. Greenlaw of Naval Air Systems Command Headquarters and by Messrs. H. Matney and Y. McGann of Naval Weapons Station, Yorktown, Va., all of whom contributed to the development and Air Force acceptance of the Mk-94 charges, is gratefully appreciated.

The senior scientists are greatly indebted to the Master, officers, and crew of USNS SANDS for the close cooperation enjoyed throughout by the embarked scientific parties. During the Pacific tests invaluable assistance aboard was also provided by Ordnance Specialists McElroy and Hall of the Underwater Demolition Team 21, Norfolk, Va.

The authors' task in compiling this chronology of events preceding and during the experimental work at sea was facilitated by the contributions of Messrs. N. P. Fisch, R. F. LaPlante, A. L. Brooks, and LCDR R. R. Miller, all of NUSC.

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## GLOSSARY

AUTOBUOY	An independent instrumented buoy that can be programmed to descend to depths down to 20,000 ft and to record ambient noise or other acoustic signals at various depths as it ascends.
AXBT	Aircraft-Deployed Expendable Bathythermograph
DSE	Defence Scientific Establishment (New Zealand)
DSENZ	Defence Scientific Establishment of New Zealand
HMNZS	Her Majesty's New Zealand Ship
JOAST	Joint Oceanographic Acoustic and System Tests
LF	Low Frequency
MABS	Moored Acoustic Buoy System
NUSC	Naval Underwater Systems Center
S/N	Signal-to-Noise Ratio
SOFAR	Sound Fixing and Ranging
SSL	Sound-Scattering Layer
SUS	Signals, Underwater Sound
SVP/STD	Sound-Velocity Profile/Salinity-Temperature-Depth
TABS	Telemetry Acoustic Buoy System
USAF	United States Air Force
XBT	Expendable Bathythermograph

## PROJECT KIWI ONE CRUISE REPORT

## INTRODUCTION

Project KIWI ONE was a far-ranging series of experiments conducted by the Ocean Sciences Department of the Naval Underwater Systems Center (NUSC) in the North Atlantic and South Pacific Oceans, the Caribbean Sea, and the Gulf of Mexico. These experiments, the plan of which is given in NUSC TD 4309,<sup>1</sup> were carried out, in part, in conjunction with the Defence Scientific Establishment (DSE) of New Zealand and the U. S. Air Force (USAF). Participation by NUSC in Project KIWI ONE was supported by NAVSHIPS PMS-302-4 Exploratory Development Program in Ocean Sciences.

The basic objectives of the experiments may be summarized as follows:

- Examine the interrelationship between acoustic volume scattering and the biology of the deep-scattering layer as a function of location and time.
- Determine the limits of low-frequency (LF) attenuation over a long, unobstructed open-ocean path.
- Provide environmental and acoustic data for validating models of propagation-loss prediction for mobile sonar systems.
- Measure the characteristics of ambient noise versus depth in the Caribbean and Gulf of Mexico.

The organizational structure of Project KIWI ONE and a listing of sponsors for the four sequential phases, as well as the participants, are shown in figure 1. Table 1 lists the senior scientist for each of the supporting facilities and phases. Table 2 summarizes the planned events during each phase, the participants in each event, and the proposed dates of each phase. A detailed description of the events is given in the appendix, which was extracted from TD 4309.<sup>2</sup>

A report of the four sequential phases of Project KIWI ONE follows.

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<sup>1</sup>Scientific Plan for Project KIWI ONE, NUSC Technical Document 4309, 10 April 1972.

<sup>2</sup>Ibid.

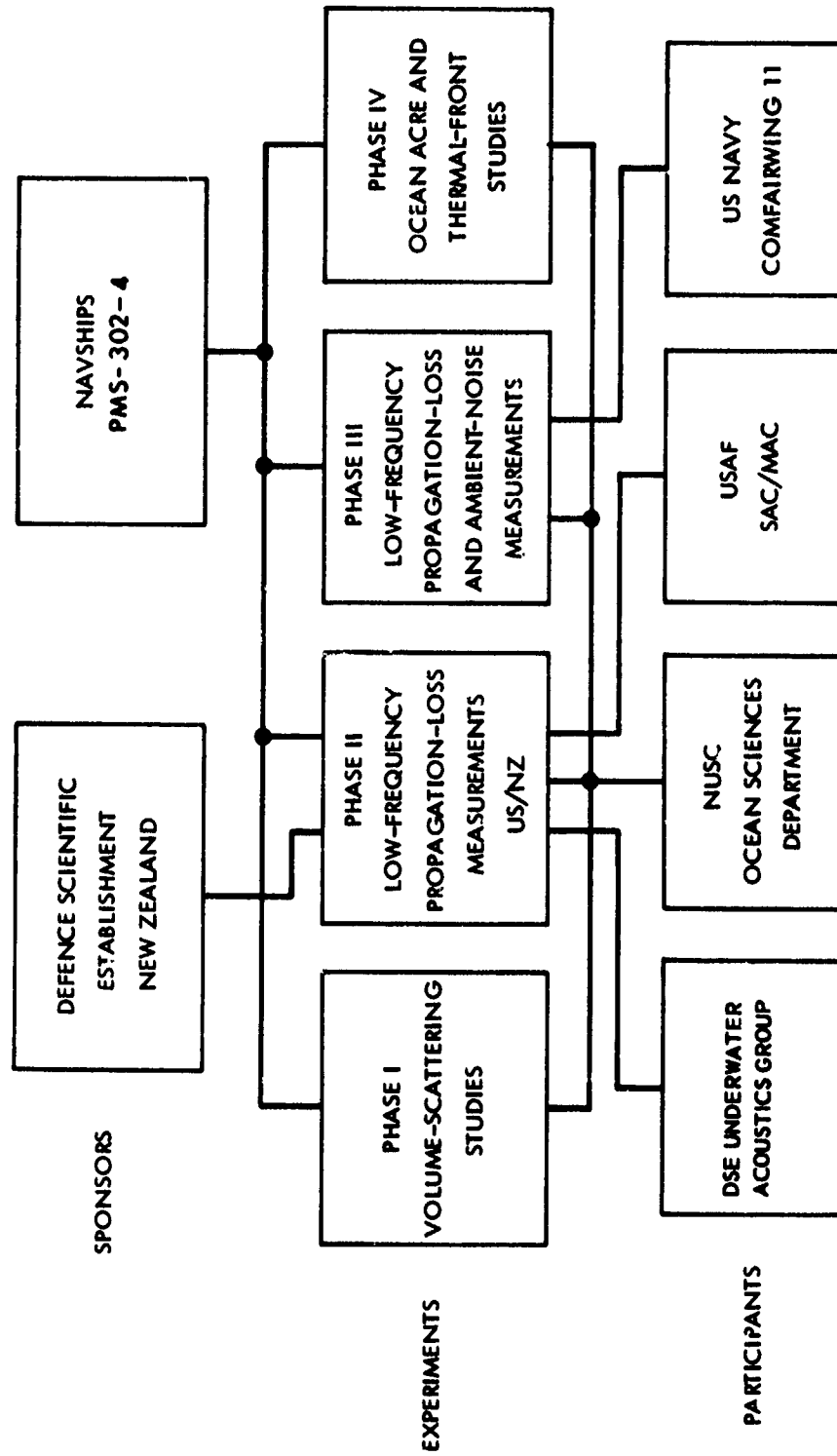


Figure 1. Organizational Structure

Table 1. Senior Scientists

Phase	Support Facility	Senior Scientists
I	USNS SANDS	N. P. Fisch, NUSC
II	USNS SANDS Aircraft (Primary) Aircraft (Secondary) HMNZS TUI	W. R. Schumacher, NUSC H. A. Caldwell, NUSC D. T. Porter, NUSC R. W. Bannister, DSE
III	USNS SANDS Aircraft	R. F. LaPlante, NUSC F. Deltgen, NUSC
IV	USNS SANDS	C. L. Brown, NUSC

Table 2. Phase and Event Summary

Phase	Inclusive Dates (1972)	Event Description	Event Designator	Support Facility
I	2-20 Apr	Acoustic Volume Scattering	A	SANDS
II	20 Apr-9 May	LF Propagation-Loss Measurements	C	SANDS, TUI, Aircraft
		Supporting Environmental Measurements	D	SANDS
III	9-25 May	LF Propagation-Loss Measurements	C	SANDS, Aircraft
		Supporting Environmental Measurements	D	SANDS, Aircraft
		Ambient-Noise Measurements	F	SANDS
IV	25 May-12 June	Thermal-Front Investigation	E	SANDS
		Biological Sampling	B	SANDS

## PHASE I OPERATIONS

### CRUISE NARRATIVE

The specific objectives of Phase I, which involved only USNS SANDS, were

- On a track between New London, Conn., and the Panama Canal, measure the biologically caused reverberation as a function of depth and location at discrete frequencies from 3.85 to 15.5 kHz when the scattering layer is stationary.
- At five one-day stations along this track measure the 3.85-kHz nighttime scattering, with emphasis on the region between the surface and the 280-ft depth.

The principal equipment used in these measurements consisted of (1) a towable transducer ("fish"), positioned at keel depth and operated at 5, 7, and 9 kHz; (2) a 3.85-kHz hull-mounted transducer (dome) used in conjunction with an "upward-looking" paraboloidal reflector system, also operated at 3.85 kHz; and (3) a suspended AN/UQN transducer operated at 13.5 and 15.5 kHz.

Figure 2 depicts the ship's test track during Phase I. SANDS departed the Naval Weapons Station at Yorktown, Va., at 2000Z on 4 April 1972, after loading explosive sound signals for use in later phases. It reached Station 1 on the following day. Reverberation data were taken in the late afternoon with the 3.85-kHz dome and the UQN transducer. At midnight these measurements were repeated. The paraboloidal reflector and fish could not be launched at this station because of the high sea state. Daytime measurements were obtained en route the following afternoon with the fish and the UQN transducer.

At Station 2 all systems were employed, including, for the first time, the paraboloidal reflector at 2000 ft. Nighttime data were recorded at frequencies from 3.85 to 15.5 kHz. The subsequent midday event en route to Station 3 was cancelled — Sea State 4 made equipment launching extremely dangerous. No reverberation was observed on the 3.85-kHz dome during this daylight period.

Improved weather conditions at Station 3 allowed the use of the UQN transducer and the 3.85-kHz dome for the midnight measurements and the deployment of the remaining systems on the following day. However, by that afternoon, various problems with the receiving circuitry, the reflector-compensation system, the hydraulic system of the launching crane, plus the hazards of a fantail repeatedly awash forced an early termination. A midnight stop en route to the next station was

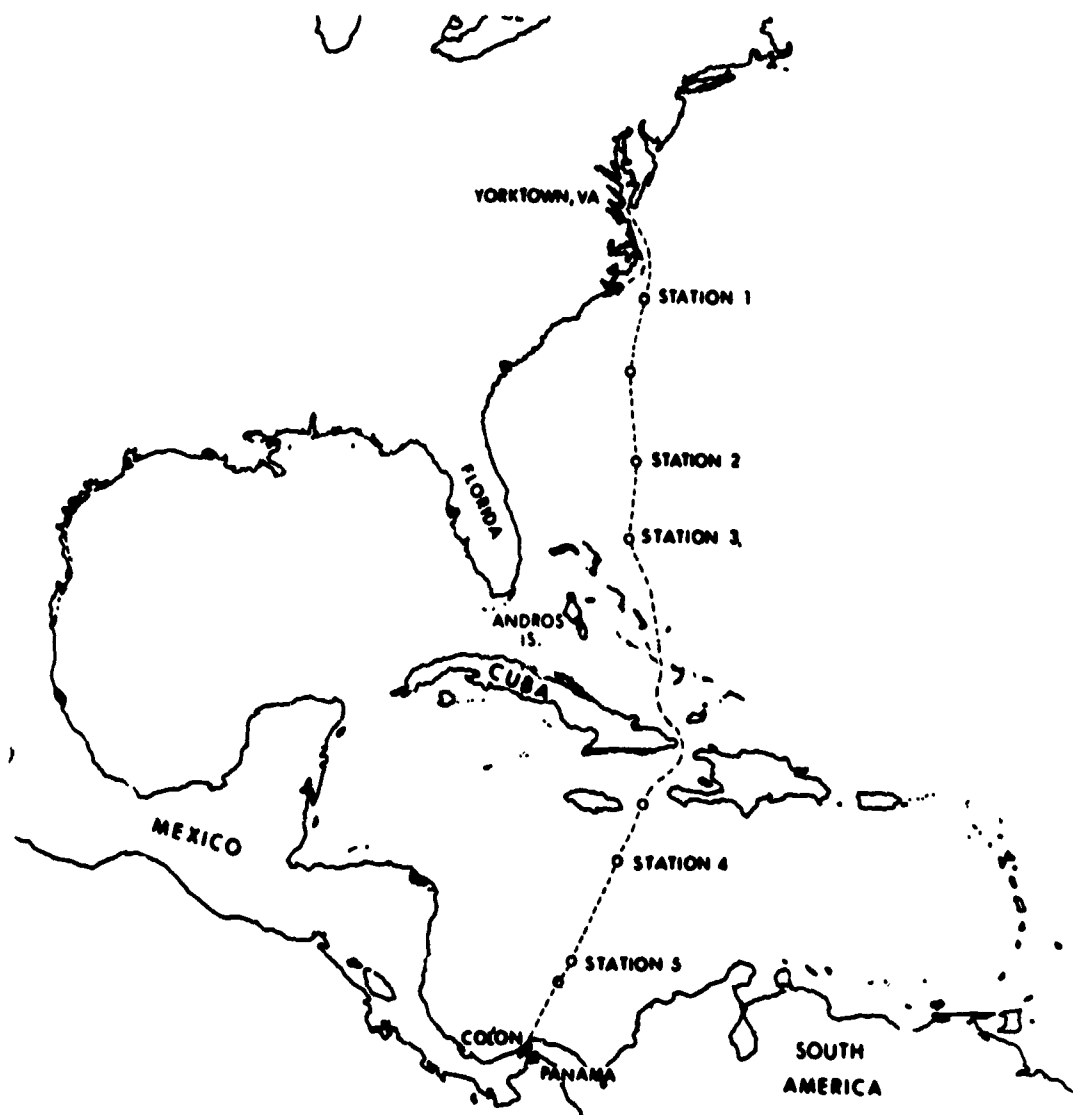


Figure 2. Test Track during Phase I

TD 4455

cancelled because of sea conditions. Subsequent noontime measurements in the southern portion of the Crooked Island Passage, in the Bahama Islands, found no measurable reverberation. East of Haiti, after 36 hours of steaming, nighttime data were taken using the 3.85-kHz dome and the UQN transducer.

In the afternoon of 12 April, SANDS arrived at Station 4 where, again, there was no observable reverberation at 3.85, 13.5, and 15.5 kHz. The fish was used successfully for nighttime measurements; however, the data from the 3.85-kHz dome were contaminated by noise, apparently caused by the rolling of the ship. At this point it was decided to remain on Station 4 for an additional 24 hours to evaluate daytime and nighttime scattering for a second time. This plan was frustrated by a defective power amplifier, and SANDS got underway for the next station.

Station 5 was reached in the early afternoon of 15 April. Despite fairly rough seas, a series of daylight measurements were made and data were obtained using the UQN transducer and the 3.85-kHz dome. The measurements were repeated at midnight. SANDS, having drifted off station nearly 30 nmi, was repositioned on the following morning for final measurements, which were completed before noontime on 16 April.

SANDS arrived at the Rodman Naval Station, Canal Zone, at 2145Z on 17 April after an 8-hour passage through the Panama Canal, thus completing the first phase operations.

#### SUMMARY — PHASE I

Scattering-layer reverberation was measured at frequencies between 3.85 and 15.5 kHz from SANDS on a track between Yorktown, Va., and the Panama Canal. These measurements were made at five stations during stable scattering-layer conditions at midday and at midnight and during stops while in transit at noon and midnight, as permitted by water depth and weather.

Table 3 summarized the reverberation data obtained during this phase in terms of date, time, location, and acoustic frequency. These data are contained in seven analog tapes and scheduled for reduction and analysis at NUSC.

Although the taking of measurements was handicapped by several failures in the electronic system and, frequently, by rough seas, the data obtained are considered to be of good quality.



Table 3. Summary of Reverberation Data for Phase I

Date and Local Time (1972)	Location	System and Frequency (kHz)
5-6 Apr, 1706-0007	34°15'N, 74°15'W (Station 1)	UQN Transducer — 13.5, 15.5; Dome — 3.85; UQN Transducer — 15.5; Dome — 3.85
6 Apr, 1322-1450	32°11'N, 74°36'W	Fish — 5, 7, 9; UQN Transducer — 13.5, 15.5; Dome — 3.85
7 Apr, 1200-1510 2200-2336	29°30'N, 74°30'W (Station 2)	UQN Transducer — 13.5, 15.5; Reflector-Dome — 3.85 Fish — 5, 7, 9; Reflector-Dome — 3.85 UQN Transducer — 13.5, 15.5
8 Apr, 2241-2314	26°45'N, 75°00'W (Station 3)	Dome — 3.85; UQN Transducer — 13.5, 15.5
11-12 Apr, 2350-0033	21°40'N, 75°30'W	Dome — 3.85; UQN Transducer — 13.5, 15.5
12-13 Apr, 2322-0029 1218 2253-2344	16°00'N, 76°30'W (Station 4) 15°50'N, 76°42'W	Fish — 5, 7, 9; UQN Transducer — 13.5, 15.5 UQN Transducer — 13.5; Fish — 5, 7, 9; Reflector — 3.85
15 Apr, 1349-1517	12°00'N, 78°00'W (Station 5)	Dome — 3.85; UQN Transducer — 13.5, 15.5
16 Apr, 2320-0017		Dome — 3.85; UQN Transducer — 13.5, 15.5
16 Apr, 1105-1140	11°56'N, 78°45'W	Dome — 3.85; UQN Transducer — 13.5, 15.5

## PHASE II OPERATIONS

## CRUISE NARRATIVE

The objective of Phase II, a joint undertaking by NUSC and DSE, was to investigate the propagation loss in the deep sound channel over a 5000-nmi track in order to establish limits of LF propagation loss and to measure LF attenuation.

The experimental sound track lay between the Galapagos Islands and New Zealand, a distance of over 5300 nmi (see figure 3). An earlier experiment had demonstrated that propagation conditions along this corridor were indeed favorable, and that the extreme range entailed could be expected to produce measurable attenuation loss even at frequencies below 100 Hz.

At first the requirement that the SUS\*-dropping aircraft start their 7000-nmi flight from runways of limited length appeared to be an insurmountable problem. However, this requirement was met by using the USAF WC-135B, a military version of the four-engine Boeing 707 equipped with fan jets, and employing multiple in-flight refueling.

Since the proposed Mk-94 SUS charges had not previously been used by the USAF with this particular combination of flight conditions and aircraft, it was necessary to establish their suitability and safety. The ensuing certification of these charges, coordinated by LCDR R. R. Miller and H. A. Caldwell of NUSC, involved three steps. First the USAF Weapons Manager reviewed the SUS charges and the WC-135B Radiosonde Dispenser as a system. Based on this review, a tentative weapon-handling procedure was drawn up. Second, the Safety Officer for the 9th Weather Reconnaissance Wing reviewed the proposed handling procedure and issued a standard-handling technique. Then dummy charges, dropped from a WC-135B at 35,000 ft over the ocean, west of San Francisco, were observed and photographed from a Navy F-4 chase plane. Next live charges were dropped, without the chase plane present, and monitored at a suitable sound fixing and ranging (SOFAR) station. The results of the drop tests, which were observed by all interested parties from the Navy and the Air Force, were presented to the Non-Nuclear Munitions Weapons Safety Board of the Air Force on 20 April. Their approval on the same day of the Mk-94 SUS charges as a safe ordnance to carry in and dispense from the WC-135B completed the certification process.

Between 18 and 24 March, the final planning details of this joint experiment were worked out at Auckland, New Zealand, by B. Olssen and R. Bannister of DSE and W. Schumacher and W. Thorp of NUSC.

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\*Signals, Underwater Sound.

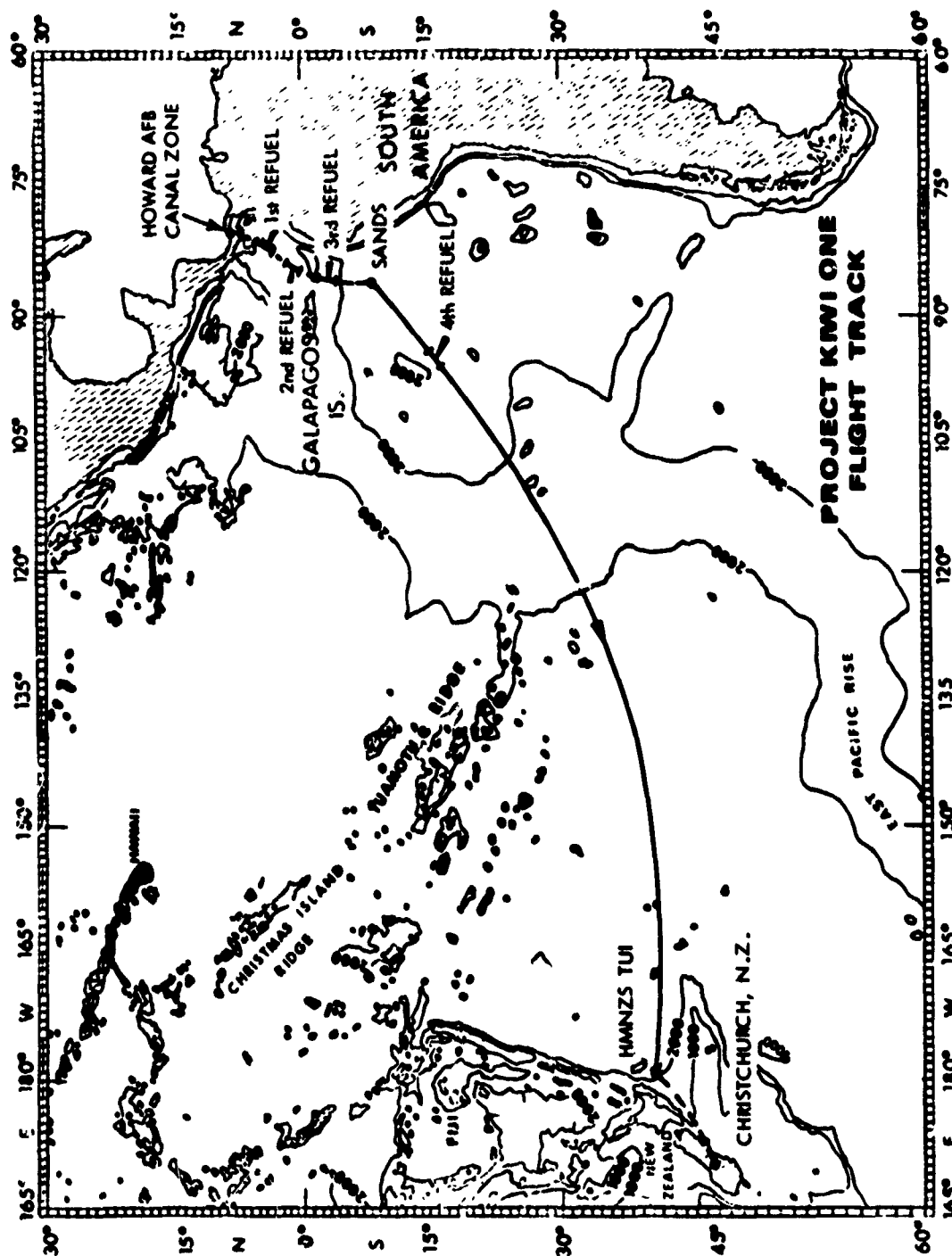


Figure 3. Route of Final Phase II Westbound Flight

Personnel for Phase II embarked SANDS at Rodman Naval Station and sailed at 1900Z on 20 April. During the four-day transit to the test site, radio communication was established with Her Majesty's New Zealand Ship (HMNZS) TUI (formerly USNS DAVIS), which was laying a supplementary shore-cabled listening system for the experiment.

When SANDS arrived at the receiving station on the evening of 24 April, a 12,000-ft sound-velocity cast was made to establish prevailing refraction conditions. On 26 April, SANDS fired a series of test charges along a 100-nmi track normal to the proposed aircraft flight path. This sequence consisted of 13 hourly 20-pound detonations at 3000 ft for the purpose of revealing any topographic obstructions along specific great-circle routes. The TUI reported that all detonations were recorded with an ample signal-to-noise ratio (S/N), and, on the basis of relative received levels, a final site at 8°37.0'S, 86°02.0'W — about 5 nmi from the original location — was selected. On the following day, while other shipboard preparations were being completed, a 5- by 5-nmi area about this position was bottom-surveyed, and the ultimate anchor point for the Moored Acoustic Buoy System (MABS) chosen.

The USAF contingent arrived at Howard AFB, Canal Zone, on 27 April. It included two WC-135B aircraft (primary and backup) and four KC-135 tankers. Their preparations, including the loading of 365 Mk-94 SUS charges on each plane, went smoothly and the target date of 29 April for commencement of the experiment was confirmed. Communication with SANDS, as well as with the project groups at New Zealand, was established and thereafter capably maintained via the Howard AFB Communication Center.

During final checkout on 28 April, the recorder in the MABS subsurface buoy became inoperative. In view of this, only the arrays for the Telemetry Acoustic Buoy System (TABS) and Joint Oceanographic Acoustic and System Tests (JOAST) were prepared for deployment during the initial westbound run.

At 1200Z on 29 April, after aircraft takeoff was confirmed via radio, both the TABS and JOAST arrays were rigged for listening in nearly ideal sea conditions. At 1445Z, the drop plane passed overhead. However, after 2 hours into the measurement portion of the flight at 17°36'S, 97°00'W, the WC-135B had an engine failure and returned to Panama (figure 4).

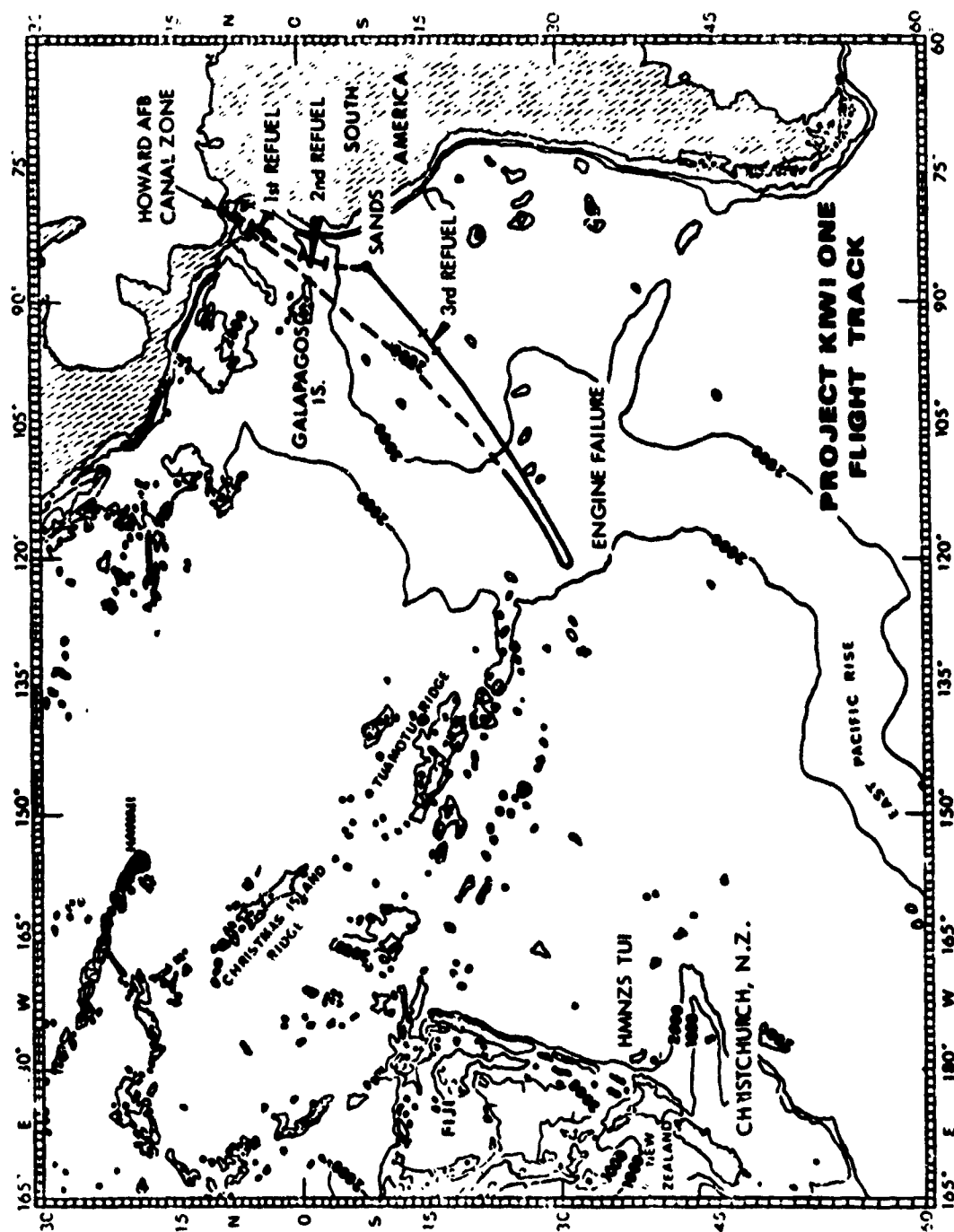


Figure 4. Route of Initial Phase II Westbound Flight

For the 70 charges that were dropped, approximately 40 detonations were recorded, tentatively indicating a dud rate of about 40 percent. This is an unusually high incidence and, based on results of the earlier certification trials, more than twice the expected rate. Signals received on the JOAST axial hydrophone were of excellent quality; however, even under the most favorable sea conditions, effectiveness of the JOAST's 800-ft hydrophone was greatly reduced by cable strumming. During the 48-hour delay incurred awaiting a replacement WC-135B from Calif., efforts were made to correct the internal electrical interference in TABS.

An operationally perfect second westbound flight was made on 1 May, as shown in the following time table:

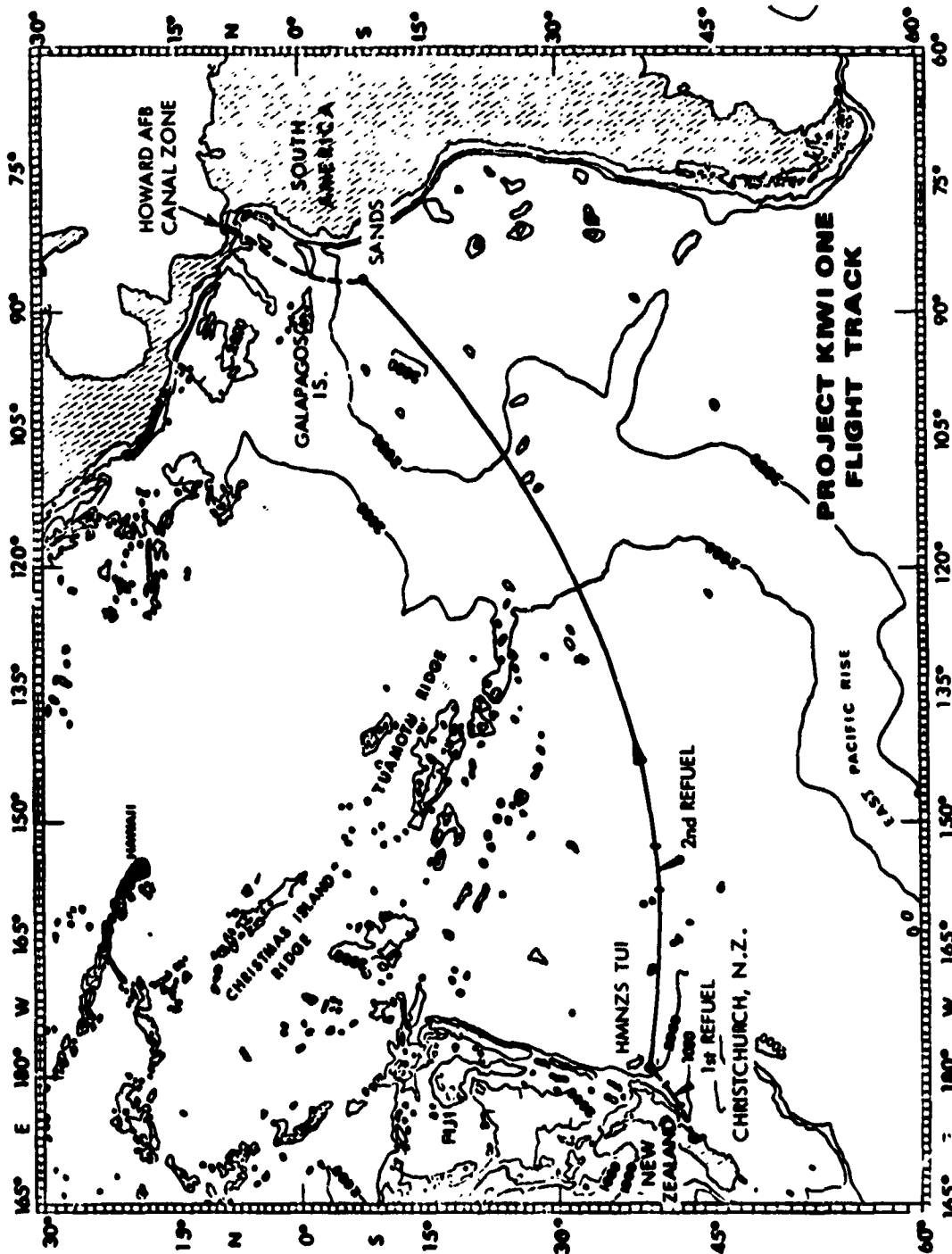
Depart Howard AFB, Canal Zone	1 May 1200Z
Arrive SANDS, Comex	1 May 1450Z
Arrive TUI, Finex	2 May 0312Z
Arrive Christchurch, New Zealand	2 May 0435Z

Total airborne time was about 16.5 hours, and good radio contact between SANDS and the primary aircraft was maintained. The TABS array had failed soon after the start of the test and, again, the JOAST deep hydrophone was the principal receiver.

Of the 358 Mk-94 charges dropped along the 5000-nmi experimental sound track, about 200 were recorded by SANDS and at New Zealand. Since there were few instances of acoustic interference at either listening site during this flight, missing items were almost entirely the result of duds.

The 48-hour aircraft turnaround period was also an occasion for an ingenious contrivance aboard SANDS, whereby the surface buoy and telemetry of TABS and the hydrophone and mooring of MABS were incorporated. This combined MABS-TABS assembly, used for the eastbound flight on 4-5 May (figure 5), performed perfectly and proved to be notably quieter than the JOAST hydrophone system. The JOAST deep hydrophone functioned well also, although a higher sea state made it somewhat less effective than before.

Because of the continued high dud rate, the original plan was modified and, again, only deep charges were dropped during the return run, except for three 800-ft Mk-61 charges each hour for indexing and comparison.



**Figure 5. Route of Phase II Eastbound Flight**

The return flight was operationally uneventful and about 2 hours shorter than the outbound leg — the result of favoring rather than opposing winds. The respective times of this flight were

Depart Christchurch, New Zealand	4 May 2137Z
Arrive TUI, Comex	4 May 2300Z
Arrive SANDS, Finex	5 May 0942Z
Arrive Howard AFB, Canal Zone	5 May 1200Z

Of the 293 charges dropped, approximately 123 detonations were recorded.

AUTOBUOY\* was deployed during both complete runs and programmed to record at 3000 ft for two 78-minute periods of each dive. Because it operated in quieter surroundings at some distance from SANDS, the recordings of the detonations were found to have a more favorable S/N (6 dB on the average) than the JOAST deep hydrophone. These two dives brought the total number of dives by AUTOBUOY to 49, in a series spanning more than 3 years of successful operation.

During the return to Panama extensive expendable bathythermograph (XBT) measurements were made to study the thermal front that separates the cold, highly-saline water of the Peru Current from the warmer tropical water near the equator.

SANDS docked at Rodman Naval Station at 1230Z on 10 May, completing Phase II of Project KIWI ONE.

## SUMMARY — PHASE II

The outcome of the Phase II operations was, in general, most satisfactory. A redundancy of listening capability, bolstered by the energy and resourcefulness of SANDS project personnel, contributed to this success. More than 300 transmissions were recorded by both DSE and NUSC over propagation ranges extending up to more than 5000 nmi. On the positive side, the sound transmission and environmental conditions affecting it were better than expected, the occurrence of potentially interfering shipping was far less, and the performance of SANDS and the essential aircraft support was eminently satisfactory. On the negative side, even with exceptionally calm weather prevailing, the most reliable listening array was handicapped by its self-generated interference; also, the dud rate of the charges was exceptionally high.

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\*An independent instrumented buoy that can be programmed to descend down to 20,000 ft and to record ambient noise or other acoustic signals at various depths as it ascends.



Subsequent Phase III experience has revealed that the dud rate is peculiar to the particular production lot of 3000-ft Mk-94 charges. It is not the result of their use under unusual conditions of altitude and speed, as was initially thought. It had been surmised that the apparent tendency for duds to occur in long, rather than random, sequences might explain the relatively few duds resulting from the small number of drops involved in preliminary certification trials. However, in the following phase, the same high rate of failure was experienced with the 3000-ft charges, in contrast to almost no failures with the 1600-ft versions of the Mk-94.

### PHASE III OPERATIONS

#### CRUISE NARRATIVE

SANDS departed Rodman Naval Station on 12 May and proceeded through the Panama Canal to commence Phase III, i. e., investigations of propagation loss and ambient noise in the Caribbean and Gulf of Mexico.

On arrival at Station 8 (figure 6), a sound-velocity cast was completed to 9000 ft. Between 1000Z and 1135Z on 14 May, TABS was launched; however, it became inoperative soon after and was replaced by the JOAST array. Because of the high sea state and strong winds prevailing, and with the resultant drift of SANDS, the effectiveness of this receiver was severely impaired by cable strumming. In spite of difficulties caused by these weather conditions, the deep hydrophone was held at a depth between 2600 and 3400 ft during the propagation measurements.

When the Navy COMFAIRWING 11 P-3 aircraft arrived on station from Howard AFB at 1840Z, test charges were dropped to ascertain the time from release to detonation for the 800-ft Mk-61 and 3000-ft Mk-94 charges. Thereafter, the opening run, extending over 900 nmi, commenced at 1916Z and ended at 2302Z. One hundred and fourteen Mk-94s were expended, of which 59 were definitely recorded by SANDS. The closing run began at 2318Z on 14 May and concluded at 0256Z on 15 May. Although only 75 of the one hundred and thirteen 800-ft Mk-61s dropped were recorded, this situation was almost entirely the result of an insufficient signal level at the further ranges rather than of nondetonation of the charges. Temperature-depth casts were obtained by Aircraft-Deployed Expendable Bathythermographs (AXBTs) every 50 nmi of the opening run.

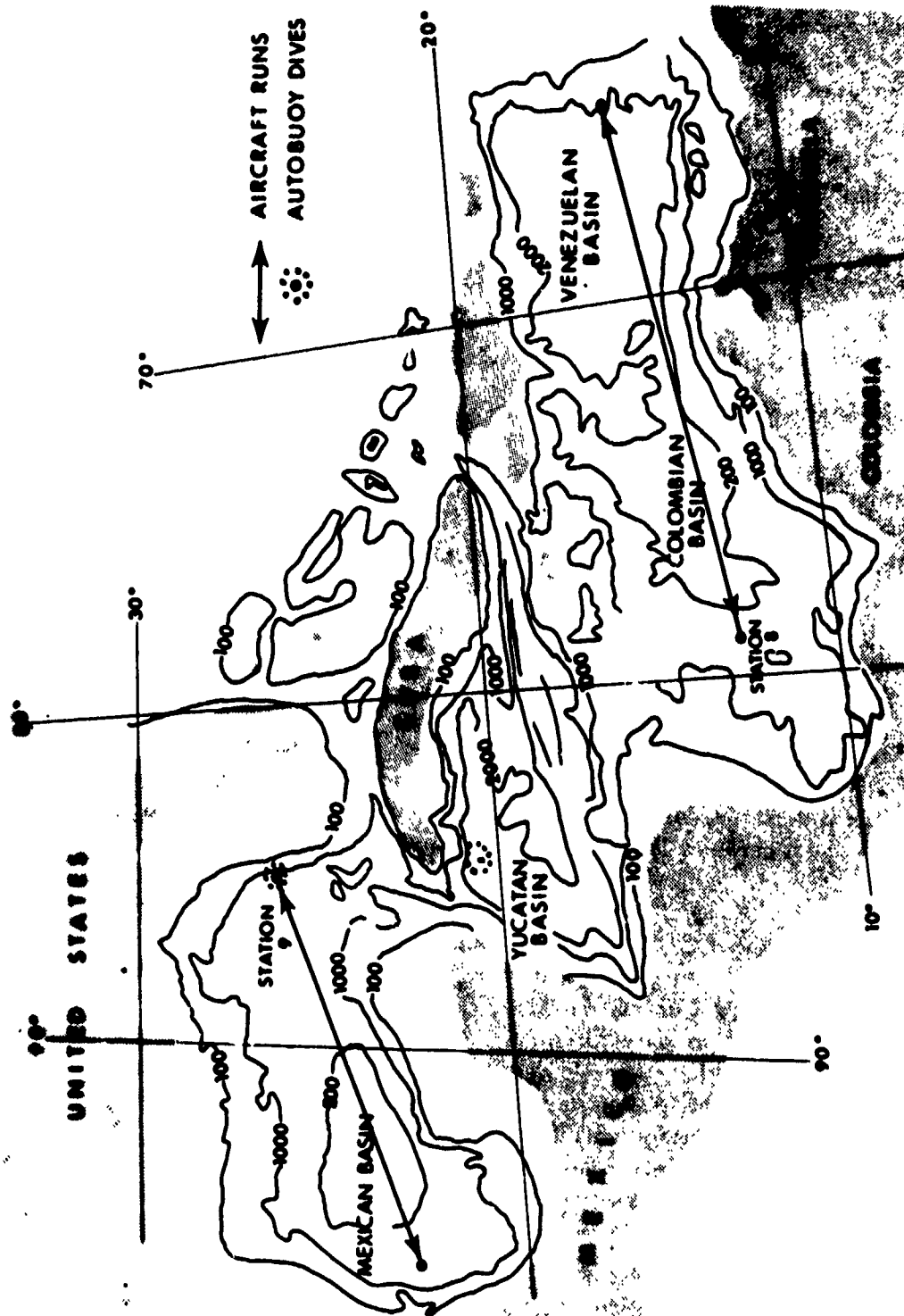


Figure 6. Phase III Test Area

At 1636Z on 18 May, while the SANDS was en route to Station 9, AUTOBUOY was launched in the Yucatan Basin (figure 6). Although it surfaced earlier than its programmed time, it did record ambient noise at three of the five planned hovering depths.\* The data obtained were reviewed on a graphic recorder aboard SANDS and, from this initial inspection, appear to be good.

While in transit to Station 9, JOAST was re-rigged for hydrophone depths of 800 and 1500 ft and then recalibrated. An extra length of JOAST cable was employed to re-rig TABS for listening at 1500 ft. TABS was also recalibrated.

SANDS reached Station 9 on 20 May and immediately launched the second AUTOBUOY dive of this phase. This time, it functioned according to its instructions, and preliminary inspection indicates good data.

The re-rigged TABS was deployed and tested for 5 hours on 21 May. Recordings of its transmitted analog noise data revealed the effects of cable strumming. In an effort to eliminate this interference, a 60-lb lead slug was attached a few feet above the hydrophone. As a result of this cable damping, some reduction in cable vibration was subsequently noted.

The P-3 aircraft reached SANDS on Station 9 at 1400Z on 22 May and, again, test charges were dropped to determine the time from release to detonation. The opening run, extending over 600 nmi, began at 1630Z and ended at 1900Z. A total of 77 charges were expended; all but one was recorded by SANDS. The closing run followed almost immediately (1916Z) and ended at 2144Z. This time only 2 of the 77 charges were duds.

As at Station 8, AXBTs were ejected and recorded every 50 nmi on the opening run.

### SUMMARY — PHASE III

Propagation-loss measurements were carried out at Station 8 in the Caribbean between 13 and 15 May. Aircraft participation was entirely satisfactory, but the dud rate was almost 50 percent for the 3000-ft Mk-94s. Propagation-loss data, recorded from the outputs of the JOAST array, appear to be unimpaired by motion-induced interference for frequencies of 200 Hz and above. As a result of cable hocking, the TABS hydrophone was lost and no data were obtained. The scheduled AUTOBUOY dive at this location was cancelled because of equipment problems and high seas, but ambient-noise observations were made at an intermediate site between Stations 8 and 9.

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\*The premature surfacing was traced to a valve-sensitivity problem.

Scheduled operations at Station 9 in the Gulf of Mexico were conducted from 21 to 23 May, with both the TABS and JOAST arrays being used. Because of the sea conditions encountered, cable strumming continued to mask any acoustic results below 200 Hz. However, aircraft support was again outstanding, and a mere 1-percent dud rate was experienced. Two successful AUTOBUOY dives were completed and two 9000-ft sound-velocity casts were obtained.

## PHASE IV OPERATIONS

### CRUISE NARRATIVE

SANDS departed the U. S. Naval Station, Bermuda, at 1200Z on 4 June to support the continued NUSC-Smithsonian Institute-University of Rhode Island study of Ocean Acre (31°30'N to 32°30'N and 64°30'W to 64°30'W, see figure 7).

As originally planned, Phase IV was to include thermal-front studies between Eleuthera and Bermuda, as well as investigations of Ocean Acre 14. However, because of earlier delays in the project, the thermal-front studies were eliminated.

The specific objectives of this phase of Project K11 ONE were as follows:

- Continue the collection of biological samples from above, within, and below the sound-scattering layer(s) (SSL).
- Obtain acoustic data on volume reverberation at 3.85, 5, 7, 9, 13.5, and 15.5 kHz.
- Record the thermal structure of the upper waters using XBTs.
- Obtain quantitative measurements of irradiance at the sea surface and at the depth of the net.
- Initiate studies on swimbladders of fish found in Ocean Acre.

For 24 hours the nets were deployed and samples were collected following a sampling regime established during earlier cruises, which consisted of, first, lowering the net to the desired depth while towing it at about 3 knots. During descent and stabilization at depth of the net, the open, four-chambered cod-end allows organisms to pass through the net. Once the net has stabilized at the desired depth, the first gate is closed and the net is trawled for one hour. Then the second gate is closed, trapping in the first chamber the organisms captured during the first hour of fishing. The third and fourth gates are closed after the 2nd and 3rd hour of trawling, respectively. Immediately following closing of the fourth gate, net retrieval is begun.

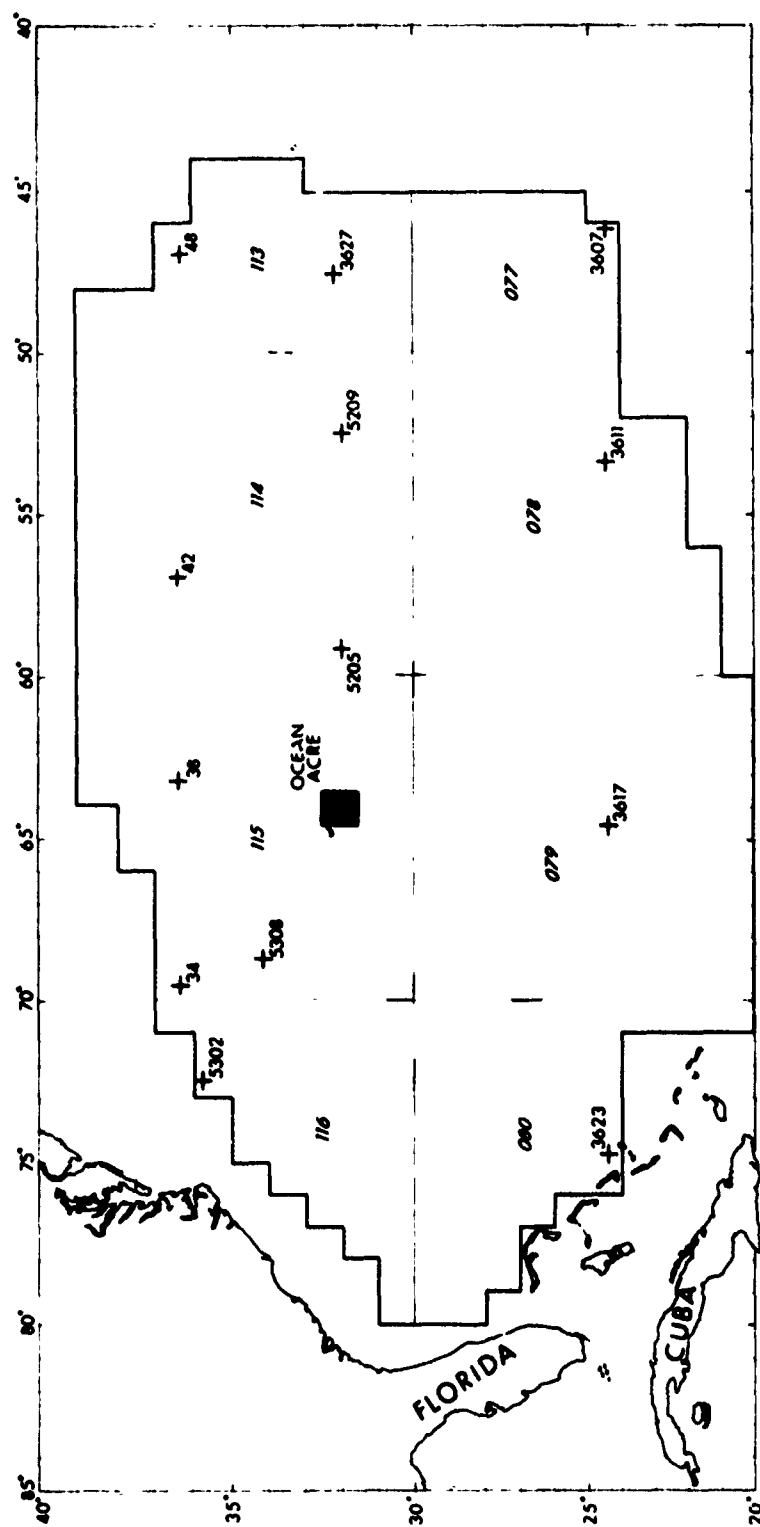


Figure 7. Phase IV Test Area

When the net reaches the surface, it contains three discrete samples, all collected from the same depth, plus a sample that contains organisms trapped by the net during its ascent (oblique sample). All organisms collected are sorted into four categories: fishes, eel larvae, cephalopods (squid and octopi), and other invertebrates (e.g., shrimp, jellyfish, etc.).

These integrated studies began at 1745Z on 4 June and ended at 0045Z on 12 June. SANDS then returned to Bermuda, arriving at 1330Z on 12 June and concluding the measurement phases of Project KIWI ONE.

#### SUMMARY — PHASE IV

A total of 31 net tows yielded 77 discrete-depth samples, 25 oblique samples, and four samples containing both horizontal and oblique components.

Eleven sets of acoustic measurements (taken at noon and at midnight) at frequencies from 3.85 to 15.5 kHz revealed the depth of the main daytime scattering layer to be between 300 and 500 meters (985 and 1640 ft). Following sundown, the main nighttime layer occurs at depths of 75 and 125 meters (246 and 410 ft).

The results of XBTs taken down to 750 meters (2460 ft) at noon and at midnight daily show a surface temperature of 22°C-23°C, a seasonal thermocline starting at depths between 20 and 60 meters (65 and 197 ft), and a permanent thermocline beginning at approximately 500 meters (1640 ft).

Measurements of natural radiant energy penetrating the waters of the sampling area (long known to have ecological importance to the sea) were obtained during each net trawl using a submarine photometer designed and built at NUSC. Preliminary analyses of these irradiance data indicate a diffuse attenuation coefficient ( $k$ ) of 0.032 to 0.039  $\ln/\text{meter}$  for the upper waters (surface to 300-400 meters, 985-1310 ft) of Ocean Acre.

Studies of fish swimbladders initiated in earlier Ocean Acre investigations were continued during this phase. Measurements and observations were made on 70 specimens belonging to 30 different species of one of the most important families of bladdered fish in the sampling area, the Myctophidae.

## Appendix

### DESCRIPTION OF EVENTS A, B, AND C\*

This appendix provides detailed explanations of Events A, B, and C.

#### EVENT A, ACOUSTIC VOLUME-SCATTERING STUDIES

##### OBJECTIVES

The objectives of Event A are as follows:

- a. Determine the volume-scattering strength as a function of depth and area at discrete frequencies over the range of 3.5 to 16 kHz when the scattering layer is nonmigratory. This will be done along the track from New London, Conn., to the Panama Canal.
- b. Determine the scattering strength of the nighttime scattering layer, concentrating on the 0- to 250-ft depth range by use of the 3.85-kHz hull-mounted transducer (dome), which is used in conjunction with an "upward-looking" paraboloidal reflector system also operated at 3.85 kHz. This is to be carried out during the five day-long stations (see table A-1) together with the preceding objective.

##### CONCEPT OF OPERATIONS

The acoustic volume-scattering strength will be determined by SANDS using both hull-mounted and towable transducers operating over the frequency range of 3.5 to 16 kHz. Data will be obtained for the following specific frequencies:

- 3.85 kHz — Hull-mounted transducer (dome)
- 5, 7, and 9 kHz — Towable transducer ("fish")
- 13.5 and 15.5 kHz — Suspended AN/UQN transducer.

En route daily volume reverberation measurements will be made for periods of 2 hours at noon and at midnight.

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\*Except for minor changes, this appendix was taken directly from Scientific Plan for Project KIWI ONE, NUSC Technical Document 4309, 10 April 1972.

Table A-1. Station Sites

Station No.	Site		Events* Conducted
	Latitude	Longitude	
1	34°15'N	74°15'W	A
2	29°30'N	74°30'W	A
3	26°45'N	75°00'W	A
4	16°00'N	76°30'W	A
5	12°00'N	78°30'W	A
6 and 7	08°40'S	86°00'W	C and D
8	10°45'N	80°45'W	C, D, and F
9	26°35'N	85°20'W	C, D, and F
10	32°00'N	64°00'W	B and E
*Event A — Acoustic Volume-Scattering Studies Event B — Ocean-Acre Measurements Event C — LF Propagation-Loss Studies Event D — Supporting Environmental Measurements Event E — Thermal-Front Studies Event F — Ambient-Noise Studies with AUTOBUOY			

At the five day-long stations SANDS will measure the acoustic volume-scattering strength of the nighttime scattering layer using the dome and paraboloidal reflector. Also reverberation data will be obtained at these stations at the previously mentioned frequencies during the two stable scattering-layer periods. Total measurement time for each period will be 4 hours.

#### EQUIPMENT REQUIRED

The following equipment, to be supplied by SANDS, will be required:

- 3.85-kHz hull-mounted transducer (dome)
- AN/UQN hull-mounted transducer
- 5-, 7-, and 9-kHz towable transducer ("fish")
- 3.85-kHz "upward-looking" paraboloidal reflector system.



## EVENT B, OCEAN-ACRE MEASUREMENTS

### OBJECTIVES

Event B is part of a continuing program whose details and objectives may be found in NUSL Publication No. 1107.<sup>A1</sup> These include net deployment for biological sampling and simultaneous volume-scattering measurements at Station 10.

### EQUIPMENT REQUIRED

The following equipment will be required for Event B:

- Sound-velocity casts/Salinity-temperature-depth (SVC/STD) system
- XBT launcher and recorder
- Hull-mounted navigation sonar AN/UQN operating at up to 20 kHz
- Towable transducer operating at 5, 7, and 9 kHz
- 3.85-kHz hull-mounted transducer (dome)
- Isaacs-Kidd midwater trawl.

## EVENT C, LF PROPAGATION EXPERIMENTS

### OBJECTIVES

Event C is to determine the characteristics of propagation loss versus frequency (10 to 1000 Hz) over (1) a 6000-nmi clear transmission path in the South Pacific Ocean and (2) 900- and 600-nmi tracks, respectively, in the basins of the Caribbean Sea and Gulf of Mexico. The resulting acoustic data, in conjunction with supporting environmental measurements, will be used in developing LF propagation-loss-prediction models for different environments.

### CONCEPT OF OPERATIONS

Upon arriving at Point XRAY (08°05'S, 86°40'W), SANDS will obtain supporting environmental measurements (Event D). Immediately following, the ship will determine the suitability of the proposed Pacific listening site by dropping a series of 20-lb charges every 10 nmi along a course bearing 141.5°T from Point XRAY

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<sup>A1</sup>Ocean Acre, NUSL Publication No. 1107, 2 April 1970.

for a distance of 100 nmi. The Defence Scientific Establishment of New Zealand (DSENZ) will be notified of the intended start time and, on the basis of received levels, will inform SANDS of the received order of the sequence. The initial and final drops will consist of two charges 5 minutes apart.

Aircraft will conduct overflights from adjusted Stations 6 and 7, along a great circle, to the western terminus at 39°20'S, 179°50'W. Three charges dropped in rapid succession will signal the start of a run. Thereafter, drops will occur on every even minute of the hour, but omitting a charge exactly on the hour. Preferably, a constant flying altitude should be maintained; if this is not possible, a log of the changes should be kept. The discretion of the aircraft commander will govern the omission of drops due to traffic or other conditions or both. Just as for the start of the run, the end of the run will be signaled by three charges dropped in rapid succession.

After 48 plus hours, the return run over the same track will be made using the same procedures and sequence of dropping charges as for the westbound run, except that the detonation depths now will alternate between 800 and 3000 ft.

At Station 8 in the Caribbean, the two runs will be made by P3 aircraft flying at 240 knots. The first run (C1A) will begin at 17°00'N, 66°30'W, proceeding thence at a constant altitude and approximate base course of 246°T toward SANDS and dropping charges that will detonate at 3000 ft every 2 minutes. Again these charges shall be released on the even minute, and the drop on the hour will be omitted. If the ship and aircraft have voice communication, the start of the run will be indicated via this net; if not, the run will begin without instruction after an interval of 15 minutes. The same sequence will be maintained, but the detonation depth will be 800 ft. Start of run C1A and completion of run C1C will be signaled by three charges dropped in rapid succession.

The two Event C runs from Station 9 in the Gulf of Mexico, though somewhat shorter than those from Station 8, are otherwise similar. However, the initial run (D1B) will begin from SANDS, opening on base course 250°T to 22°55'N, 96°10'W, with charges set for 1500 ft. In the absence of voice communication, the return run (D1C) will proceed after 15 minutes and employ charges set to detonate at 800 ft. The same signal will be used to indicate the end of the first and start of the second run.

At Stations 8 and 9, AXBTs will be dropped every 50 nmi along the track in one direction only -- for a total of 33.

Table A-2 summarizes the six propagation runs of Event C and the main parameters of each.

Table A-2. Summary of Event C Aircraft Runs

USNS SANDS Receiving Site		Run Designator (Open/Close) Re SANDS	Base Course (°T)	Source Depth (ft)	Length of Run (nmi)	No. of Charges (SUS)
Latitude	Longitude					
08°40'S	86°00'W	A1A (O)	•	3000	6000	375
08°40'S	86°00'W	B1A (C)	•	800/3000	6000	375
10°45'N	80°45'W	C1A (C)	246	3000	900	125
10°45'N	80°45'W	C1C (O)	066	800	900	125
26°35'N	85°20'W	D1B (O)	250	1600	635	100
26°35'N	85°20'W	D1C (C)	070	800	635	100
* Western termination at 39°20'S, 179°50'W						

## EQUIPMENT REQUIRED

The following equipment will be required for Event C:

- MABS-1, modified for single-hydrophone operation (Phase II only)
- TABS 2-element array
- JOAST dual-hydrophone suspended array
- AUTOBUOY
- SVP/STD system
- XBT launcher and recorder
- Aircraft with AXBT and SUS launchers.